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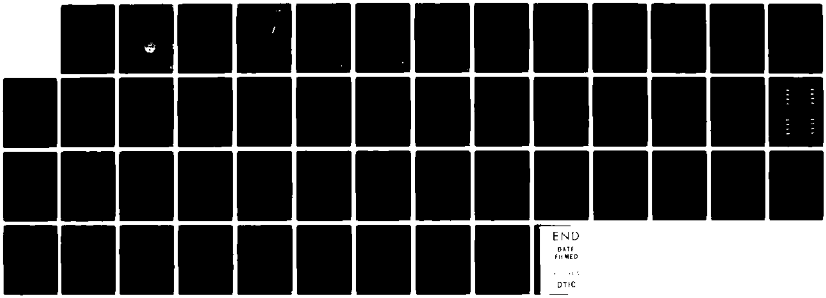

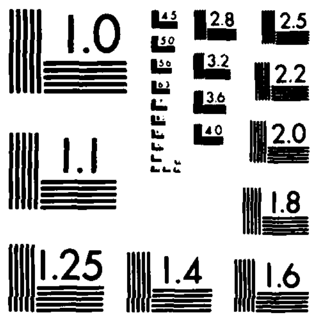

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NAVY PERSONNEL RESEARCH CENTER SAN DIEGO, CALIFORNIA

NAVY PERSONNEL RESEARCH
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San Diego, California 92152

NPRDC Special Report 83-27 April 1983

INDEPENDENT RESEARCH AND INDEPENDENT EXPLORATORY DEVELOPMENT AT THE NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER—FY82

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FOREWORD

The Independent Research (IR) program at the Navy Personnel Research and Development Center has been active since the Center was formed in 1973. It is funded under PE61152N. The Independent Exploratory Development (IED) program was initiated in FY76 and is funded under PE62766N.

This report is submitted to fulfill the requirement for an annual IR/IED report (NAVMATINST 3920.B). It provides synopses of FY81-82 IR/IED projects, the IR/IED funding profile, and a list of publications and presentations on IR/IED projects.

JAMES F. KELLY, JR
Commanding Officer

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Technical Director

CONTENTS

INDEPENDENT RESEARCH (IR) PROGRAMS

The Navy Personnel Research and Development Center (NAVPERSRANDCEN) has been conducting Independent Research (IR) since its establishment in 1973. The resources provided for this program have been used to develop research methods and techniques related to training, employment, and performance of people in the Navy. In FYs 81 and 82, IR work has been concentrated in the areas indicated in Table 1. Selected projects within these areas are described in the remainder of this section.

IR/IED work units for FY83 are presented in Appendix A; and IR/IED publications and presentations, in Appendix B.

Table 1

IR Work Units for FY81-82

Independent Research			Dollars (in thousands) FY81	FY82
ZR000-01-042-04:	SELECTION AND RETENTION			
-01	Measurement Theory and Methods in Personnel Research		83	68
-01.03	Differential Worth for Optimal Individual Placement[a]	Dr. L. Kroeker Code 12	10	5
-01.04	Unobtrusive Measures of Attitude	Dr. C. A. Robinson Code 14	12	0
-01.05	Methods for Clustering Tasks	Mr. R. Chatfield Code 12	15	0
-01.06	Models for Personnel Management	Mr. J. Silverman Code 11	40	30
-01.07	Models for Calibrating Multiple-choice Items	Dr. J. B. Sympson Code 12	6	0
-01.08	Cognitive Speed Tests	Dr. B. Rimland Mr. G. E. Larson Code 01C	0	21[b]
-01.09	Adaptive Ability Tests	Dr. D. Wetzel Code 12	0	3
-01.10	Models and Measures of Human Performance	Dr. R. C. Sorenson Code 03	0	9[c]

[a]Described in detail in previous IR/IED report, NPRDC SR 82-27 (Rimland, 1982), (AD-A117 630).

[b]Being continued under FY83 work unit ZR000-01-042.003 (see Appendix A).

[c]Being continued under FY83 work unit ZR000-01-042.005 (see Appendix A).

Table 1 (Continued)

Independent Research			Dollars (in thousands) FY81	FY82
-03	Retention of Quality Personnel		95	0
-03.01	Methods for Projecting Petty Officer Retention	Dr. E. Curtis Code 16	65	0
-03.02	The Reenlistment Decision Process	Dr. L. M. Doherty Code 301	30	0
-042-06:	LEARNING AND TRAINING			
-01	Instructional Psychology		77	141
-01.01	Enhancement of Information Acquisition and Storage[a]	Dr. J. Ellis Code 13	20	42
-01.02	Delayed Feedback in Acquisition and Retention	Dr. N. Van Matre Code 14	13	0
-01.03	Improving Language-learning and Problem-solving Abilities[a]	Dr. R. Wisher Code 13	44	5
-01.04	Metaphors and Analogies in Training	Dr. S. Hearold Code 15	0	30
-01.05	Cognitive Storage Mechanisms and Learning to Read	Dr. M. Baker Code 15	0	50
-01.06	Oculomotor Training for Pilots	Mr. W. Thode Code 14	0	14[b]
-042-08:	GROUP BEHAVIOR			
-03	Group Performance Effectiveness		0	51
-03.01	Group Problem-solving in Operational Settings	Dr. W. Montague Dr. E. Hutchins, Jr. Code 13	0	1
-03.02	Organizational Effectiveness of Program Management Offices	Mr. T. Enderwick Mr. T. Koslowski Code 16	0	50
TOTAL			255	260

[a]Described in detail in previous IR/IED report, NPRDC SR 82-27.

[b]Being continued under FY83 work unit ZR000-01-042.010 (see Appendix A).

Measures Of Task Proximity

Background

Cluster analysis is frequently used to group together occupations or jobs that have similar tasks, attributes, or other work-related requirements. Such cluster profiles are useful for aligning training curricula with actual work performed and for streamlining occupational classification systems by combining administratively separate jobs into one actual job type. The Comprehensive Occupational Data Analysis Program (CODAP) was developed by the Air Force to fill these needs and is widely used by both military and civilian organizations. The data sets analyzed are typically responses of job analysts or job incumbents to items within a structured task inventory. An important decision that can affect the cluster analysis solution is the selection of a proximity measure to assess the degree of similarity among patterns of responses.

All U.S. military services use the powerful, computer-based clustering procedures available in CODAP. While recent research has suggested that simple binary measures may be able to capture as much profile information as do continuous measures, cluster solutions have not been compared empirically by applying various proximity measures to occupational data. This IR project was directed toward making such a comparison.

Approach

Data collected by the Navy Occupational Development and Analysis Center consisted of three samples of job incumbent profiles. Each sample consisted of 250 profiles, indicating time spent on various tasks and based on a 5-point scale. For each sample, 16 proximity matrices were derived with each matrix based on the application of one of 3 continuous or 13 binary proximity measures. The CODAP clustering procedure was applied to seven selected proximity matrices from each of the three samples. Evaluation of the binary measures was based on the extent to which the binary matrices and cluster solutions were objectively similar to those based on continuous measures.

Conclusions

1. The Jaccard and Dice (see Pass & Chatfield, 1982) proximity measures are consistently powerful, capable of capturing more profile information than many other binary measures.

2. The performance of a proximity measure in cluster analysis can be strongly affected by the proportion of zeros in the data analyzed.

3. The use of selected binary proximity measures yields cluster solutions highly similar to those based on continuous proximity measures.

4. Since the high proportion of zeros in the incumbent profiles analyzed are typical for this type of data set, the findings are generalizable to data collected from other occupational inventories.

Application

Based upon this methodological study, the Jaccard proximity measure was adopted and programmed into CODAP System 80, an enhanced version of CODAP developed by the Department of Defense that is currently operational in the Navy and Marine Corps.

Note. This work was accomplished under FY81 work unit ZR000-01-042-04-01.05: Methods for Clustering Tasks. A more extensive discussion of this work is provided in NPRDC TR 82-36 (Pass & Chatfield, 1982) (AD-A112 930).

Models for Personnel Management

Purpose

The management of human resources as a policy and planning enterprise is a relatively new phenomenon. The purpose of this effort was to assess the state of the art in human resource management for both public and private personnel systems.

Approach

The small body of pertinent scientific literature was reviewed and a managerial perspective was derived from the theoretical and technical features of manpower planning research and practice.

Accomplishments

A case study was developed that centers on the problems of acquiring and retaining engineering manpower. Problems occur when a high technology firm is acquired by a larger, more conventional manufacturing concern. This case study illustrates many of the interrelated factors involved in managing the internal labor market of an organization.

Along with the case study, the internal personnel structure and flow properties of public and private manpower systems were examined. After a description of internal supply and demand, consideration was given to (1) the rationale for personnel planning, (2) the relationship of a personnel system to its external environment, (3) the state of the personnel inventory, (4) methods for forecasting personnel losses and determining gains, and (5) methods for controlling the personnel system.

The case study and the assessment of personnel systems in terms of internal supply and demand represent four chapters of a book being prepared on manpower planning.

Note. This work was accomplished under FY81-82 work unit ZR000-01-042-04-01.06: Models for Personnel Management.

A New Model for Calibrating Multiple-choice Items

Background

The effectiveness of personnel selection procedures based on objective assessments of individual aptitudes and personality characteristics has been well documented. Aptitude measurement, in particular, has been widely used in industry, the civil services, and the military. The Armed Services Vocational Aptitude Battery (ASVAB), for example, is currently the principal mechanism for identifying candidates for military enlistment who are likely to succeed in various military occupations.

Since about 1920, the practice of personnel testing has depended heavily on advances in the theory of test reliability and validity. These advances have resulted in various improvements in the traditional number-correct-scored personnel test, but, in recent years, it has become increasingly apparent that further improvements in the assessment of individual aptitudes require new theoretical developments.

Item Response Theory

In the last 10 years, a new theoretical approach to test construction, scoring, and evaluation has emerged that may lead to important new advances in personnel testing. This approach is known as item response theory (IRT). The basic assumption underlying IRT is that the probability of selecting a particular response to a test question is related to a person's level of ability (or other relevant personal characteristic) by a specified mathematical function. What differentiates various implementations of IRT is the form of the mathematical function that is assumed.

The simplest IRT models assume that the probability of a correct response to a test question is a function of only two parameters--a person parameter that indexes ability and an item parameter that indexes item difficulty. A more adequate IRT model that is widely used incorporates these parameters plus two more item parameters. One of the additional item parameters takes into account the fact that low ability people can sometimes answer a multiple-choice question correctly by guessing. The other added item parameter provides an index of the discriminating power of the item. In applications of this model, items that are known to discriminate well between low and high ability people are given more weight when an individual's level of ability is estimated.

The IRT models described above have two drawbacks. First, they classify responses to aptitude questions as either correct or incorrect. They make no distinction among the different incorrect responses that a person might select. Information about a person's level of ability that could be extracted by taking into account which particular incorrect responses have been selected is lost when these models are used. Second, these models assume that the probability of a correct response to an item is a strictly increasing monotonic function of ability; that is, the probability of a correct response always increases as ability increases. In our research, evidence suggests that this assumption is too restrictive.

Approach

Data were analyzed from 125 word knowledge items and 145 arithmetic reasoning items that had appeared in operational forms of the Scholastic Aptitude Test (SAT), published by the Educational Testing Service. For most of the items, the proportion of

Note. This work was accomplished under FY81 work unit ZR000-01-042-04-01.07: Models for Calibrating Multiple-choice Items.

correct responses tended to increase monotonically as ability increased. However, for about one item in six, the proportion of correct responses tended to decline as ability increased from very low to moderate levels, and then to increase as ability rose from moderate to high levels. This finding was attributed to the presence in some of the items of one or more "plausible" incorrect responses that were more attractive to examinees at middle ability levels than to those at low ability levels.

If a significant number of items in a given aptitude domain have nonmonotone regressions of the type described above, it is clear that current IRT models cannot provide an adequate basis for personnel testing in that domain. In order to deal with this problem, a new IRT model based on the multivariate logistic function was developed.

The new IRT model takes into account the characteristics of each item response. The various incorrect responses to a multiple-choice question are kept distinct, and the tendency for people at different ability levels to find different responses differentially attractive is reflected in the parameters of the model. Also, the model is flexible enough to allow fitting of nonmonotone item-ability regressions when they occur. The new model has been applied to selected SAT items and found to fit the available data very well.

Conclusions

If this new IRT model is adopted for the calibration of test items, two immediate benefits can be realized. First, fewer items will have to be rejected for lack of fit to the model. More items can be retained for the construction of new aptitude tests. Second, once tests have been assembled, the use of information about which incorrect alternatives an individual has selected will improve our estimates of ability. This will increase the reliability of tests of any given length and will also allow the use of shorter tests to achieve prespecified levels of reliability. The latter possibility could lead to significant savings in testing time.

Cognitive Speed and Learning Potential

Background

There is a long-standing, widely recognized need for a method of testing intelligence that is fast, easy to administer, culture-free, and predictive of meaningful criteria, such as completion of or achievement in training.

Current military testing programs employ conventional paper-and-pencil tests that are basically similar to those used in World War II. While useful, such tests have long since reached the upper limit of their utility. Recent developments in the fields of cognitive science and computerized adaptive testing offer considerable promise for improving the technology for discovering and measuring an individual's talents and aptitudes. In particular, cognitive scientists are finding that simple tests that provide an index of how quickly and accurately a person can perceive a simple stimulus may yield a good deal of information about the person's underlying mental capacity.

Approach

The purpose of this work is to develop computer tests of cognitive speed and to assess their effectiveness as predictors of performance. Two hypothesized measures of cognitive speed, inspection time (IT) and reaction time (RT), are of particular interest.

IT tests generally require the subjects to discriminate between rapidly presented stimuli, usually lines. A typical display might be two horizontal lines of unequal length, with the subject simply being asked which line was longer. The exposure duration for the lines is gradually reduced until the subject's threshold is found, with threshold defined as the duration in milliseconds at which the subject's judgment is correct on a predetermined percentage of trials (usually 97.5%; Nettlebeck, 1982). An analogous series of trials using vertical lines is sometimes employed along with, or in place of, horizontal lines. Forward and backward masking ensures that responses are based on information that has actually been encoded rather than on afterimages or other peripheral (as opposed to central) processes. The mask is a longer line that the subject perceives as covering the two stimulus lines before and after their presentation. The subject's resultant inspection time or threshold value is thereby presumed to be largely the result of speed of information processing.

Experimental studies using inspection time procedures have found significant correlations, ranging from -.25 to -.95, between IT and more traditional measures of intelligence. Further, IT remains fairly stable from one experiment to another and does not appear to be influenced by practice. A recent review by Nettlebeck (1982), however, suggests that the reported correlations between IT and IQ measures may have been inflated by including subjects with lower than average intelligence. It is possible that the high correlations reported were the consequence of an excessively wide spread of IQ scores, which dipped into and below the mildly retarded range. Nettlebeck (1973, 1982) reports a correlation of -.13 between IQ and IT in nonretarded subjects of above average intelligence (IQ from 112 to 135+), and -.34 for a group of college students of average and

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Note. This work was accomplished under FY82 work unit ZR000-01-042-04-01.08: Cognitive Speed Tests.

above average intelligence. The present study will attempt to determine if IT measures provide useful data, given the range of intelligence levels found in military populations. Further, by analyzing IT measures in conjunction with scores from traditional tests, it is hoped to gain a better understanding of cognitive functioning.

RT is another measure of cognitive speed. Several investigators have reported promising results using RT measures (e.g., Carlson & Jensen, 1982; Jensen, 1980). The most basic RT experiment involves measuring the linear increase in reaction time to visual or auditory stimuli as a function of the amount of information presented. A typical console RT display is shown in Figure 1.

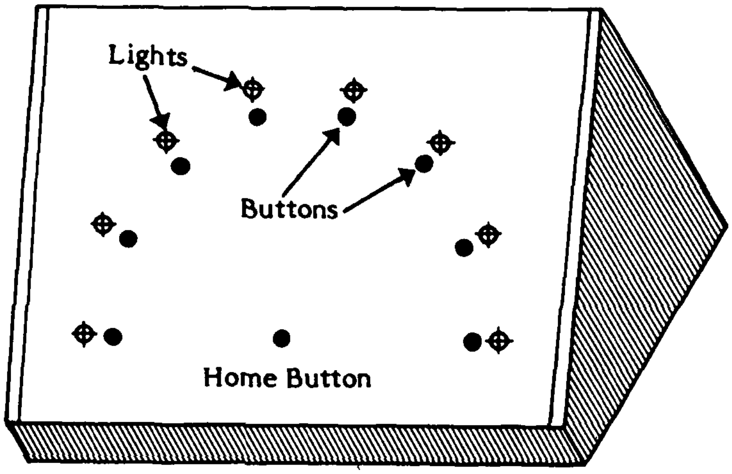

Figure 1. A typical RT display console.

The subject presses the home button until a light associated with any one of the eight stimulus buttons is activated. When the light comes on, the subject responds by removing his finger from the home button and pressing the associated target button as quickly as possible. Reaction time in this case refers to the interval between onset of the light and removal of the subject's finger from the home button.

Progress

With the assistance of Professors Tom Boyle of Purdue University and Christopher Brand of the University of Edinburgh, who were visiting faculty members at NAVPERSRANDCEN during the summer of 1982, a battery of 10 computer-presented tests of inspection and reaction time were reprogrammed on a TRS-80 microcomputer. The test battery is being administered to a sample of 150 incoming students at the Basic Electricity and Electronics School at the Naval Training Center, San Diego. When the testing is complete, the scores will be analyzed in conjunction with school grades and ASVAB scores to evaluate the cognitive speed tests as predictors of school performance.

The IT tests are adaptive; that is, the computer presents the subject with an easier item if he responds incorrectly and a more difficult item if he answers accurately. The battery includes several variations of the same test to permit determining the effects of such variables as stimulus intensity and forward and backward masking.

Regression Analysis of Reasons for Leaving the Navy

Background

The retention of qualified petty officers is a problem of considerable magnitude for the Navy. It is important to understand the reasons for separation from the Navy in order to provide recommendations for ameliorative policy changes. The Enlisted Separation Questionnaire (ESQ) is a data source for identifying these reasons. It consists of 10 background questions and 30 items listing reasons for leaving the Navy (e.g., "working hours too long"). Individuals respond to each reason on a 5-point scale ranging from "no importance" to "extremely important."

Previous work employed simple regression analysis to predict first-term reenlistment. The present effort applied hierarchical multiple regression (HMR) to the ESQ data to determine the relationship between the number of completed enlistments and the reasons for separation.

Objectives

The objectives of this effort were to determine (1) if the hierarchical multiple regression method is useful in analysis of the ESQ, and (2) the relationship between the number of completed enlistments and importance of separation reasons for specific subclasses of individuals as well as for the total group leaving the Navy.

Approach

Approximately 6500 enlisted personnel completed the ESQ upon discharge from the Navy during FY80. Factor analysis of the ESQ reasons for leaving the Navy yielded the following eight factors:

1. Leadership.
2. Skill utilization.
3. Quality of benefits.
4. Loss of benefits.
5. Regimentation.
6. Nonpermanent home.
7. Amount of work.
8. Pay.

Biodemographic variables from the ESQ were used to classify the sample into mutually exclusive subgroups (gender, education, pay grade, etc.). The correlation between number of completed enlistments and importance of each ESQ factor was then determined. HMR was used to establish the relationship between the number of completed enlistments and each ESQ factor for the mutually exclusive subgroups.

Note. This work was accomplished under FY81 work unit ZR000-01-042-04-03.02: The Reenlistment Decision Process. A more extensive discussion of this work will be provided in a NPRDC TN (Doherty & Cowen, in press).

Findings

As shown in Figure 2, the number of completed enlistments correlated positively with loss of benefits (.21), and negatively with leadership (-.14), skill utilization (-.24), and regimentation (-.16). These correlations were statistically significant. As the number of enlistments increases, loss of benefits becomes more important as a separation reason, and skill utilization, leadership, and regimentation become less important. However, the strength of the relationship between importance of leadership and number of completed enlistments was different for pay grade, education, and rating. Moreover, the strength of the relationship between importance of regimentation and number of completed enlistments was different for pay grade, marital status, fleet, and gender.

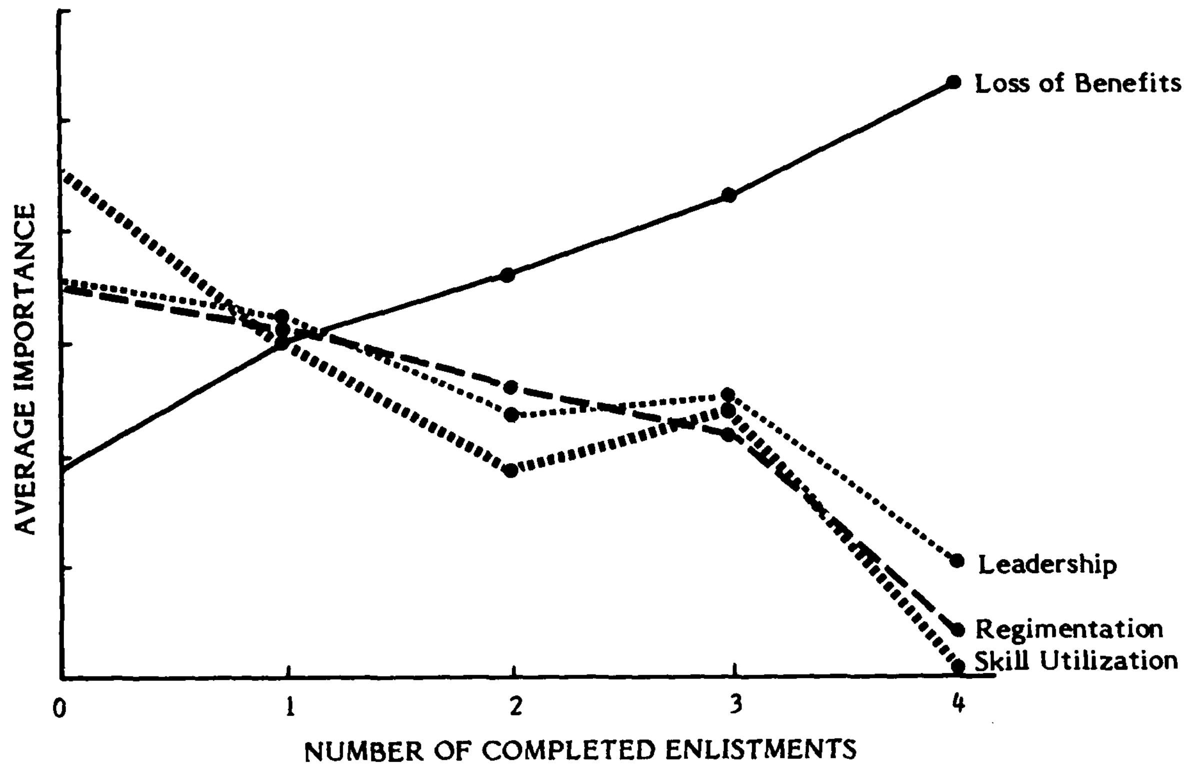

Figure 2. Relationships between completed enlistments and importance of ESQ factors.

Delayed Feedback In Acquisition And Retention

Problem and Objective

The Navy's computer-managed instruction (CMI) system, personalized system of instruction (PSI), and precision teaching are instructional systems that provide immediate feedback to strengthen student learning. However, immediate feedback can be expensive in terms of both student time and instructor time. Evidence is mounting that delayed feedback produces equal learning and, frequently, superior retention, at least when multiple-choice or fill-in test items are used. The objective of this series of experiments was to examine the relationship between the timing of feedback and long-term retention under classroom conditions.

Approach

Three experiments were conducted in courses taught according to PSI principles. Experiment I examined retention as a function of feedback-delay interval, using short-answer essay tests. Experiment II varied feedback-delay interval, informational quality of feedback, and test item type. Experiment III examined delay and item type.

Findings

This series of experiments showed no evidence of superiority for either immediate or delayed feedback. Feedback delay did not impair learning in any of the three experiments in terms of acquisition, retention, or study time, regardless of quality of feedback or test item type used. Subjects in the immediate feedback conditions reported no more initial errors than did those in the delayed feedback conditions. Further, different types of feedback (varying the amount of information) did not produce differential levels of retention. The repeatable quizzing aspect of PSI probably makes feedback a less potent variable than it is in other types of courses, because students have to learn smaller quantities of material for each test and have many opportunities to learn from whatever type of feedback is provided. The expense and trouble involved in providing immediate feedback do not appear to be warranted in these types of learning situations. Operators of the Navy CMI system have continued to apply procedures consistent with these findings.

Note. This work was accomplished under FY81 work unit ZR000-01-042-06-01.02: Delayed Feedback in Acquisition and Retention. A more extensive discussion of this work is provided in NPRDC TR 83-13 (Lockhart, Sturges, Zachai, Dubois, & Groves, 1983) (AD-A125 802).

Metaphors and Analogies in Training

Background

Metaphors and analogies have been used as teaching devices at least since the time of Plato. Intuition and empirical studies suggest that metaphors can increase comprehension, retention, transfer, and interest. The key criticism of using metaphors and analogies in instruction is that they are imprecise and potentially misleading. They also can lead to misunderstanding when students do not have the necessary prerequisite knowledge about the metaphor or analogy to apply it to the new topic.

Metaphors, analogies, and their close relatives, similies and models, are one way of relating new knowledge to what is already known and of using one subject to teach another subject. The terms "metaphor" and "analogy" have distinct definitions but, as instructional strategies, are used interchangeably. They mean any type of figurative language, or graphic or physical model, that describes one thing in terms of another—that is, any nonliteral similarity comparison used for explanation.

Although single-word methaphors are found in instructional material, the present study addressed the macro-level metaphor: one system or domain described in terms of another system or domain. Examples of macro- or system-level metaphors are light explained in terms of water waves, Campbell's billiard ball model for the kinetic theory of gases, and the hydraulic model of the blood circulation system.

Purpose and Approach

Given the pros and cons of using metaphors in instructional materials, this effort investigated the characteristics of good metaphors, and when and how they should be used to capitalize on their positive attributes while avoiding imprecision and misunderstanding. The desired product was a set of guidelines on the appropriate selection and use of metaphors and analogies for instruction. To develop the guidelines, two approaches were taken. First, 21 computer and 31 electricity texts were analyzed to determine how analogies were used in teaching basic computer concepts and basic electricity. Then, the empirical and theoretical research on instructional metaphors, consisting of more than 50 experimental studies and 100 theoretical articles, was reviewed.

Results

Fifteen prescriptive guidelines were developed for using metaphors and analogies as an instructional strategy. The guidelines are not algorithms; rather, they assist in answering three classic questions in curriculum development: what to teach, how to teach it, and when to teach it. Guidelines 1 through 9 specify what the characteristics of appropriate analogies are, 10 through 12 specify how analogies should be incorporated into instructional material, and 13 through 15 specify when analogies should be used. These guidelines are listed below.

1. Choose an analogy for a superordinate concept over different analogies for each of the subordinate concepts.

Note. This work was accomplished under FY82 work unit ZR000-01-042-06-01.04: Metaphors and Analogies in Training.

2. Choose an analogy that is no more complex than the subject matter.

3. Choose an analogy from the students' experiences; that is, an analogy with high familiarity.

4. Choose an analogy that comes from a distinctly different field of knowledge than the subject matter.

5. Choose an analogy with high imagery and high concreteness over one with low imagery and low concreteness.

6. Avoid analogies with connotations that are counterpurpose.

7. When teaching a concept, use an analogy that shares more relevant attributes and fewer irrelevant attributes with that concept. When teaching a rule or principle, use an analogy that shares more of the relevant relationships (operations) among the concepts comprising the rule or principle.

8. If necessary, use an unfamiliar analogy only if its content is taught before the analogy is used, and if the gain in understanding is more than the added burden of explanation.

9. Use multiple analogies for important or complex concepts and principles. Use to clarify relevant and irrelevant attirbutes, emphasize and clarify selected relationships, and supply "missing" relevant relationships.

10. Use analogies as advance organizers, introductions, and helps.

11. Provide all necessary cues to the inclusion of an analogy. Reduce reliance on student's learning strategies. (This is a key difference from the use of metaphors in literature.)

a. Identify the analogy as an analogy. Distinguish between the analogy and the subject matter or examples.

b. Specify that the analogy involves a comparison and state the basis for the comparison. Specify the limits of the generalization.

c. Specify how the analogy can mold one's thinking.

12. Move beyond the analogy to the formal, literal definitions and rules.

13. Use an analogy when the material cannot be readily assimilated into the student's existing knowledge structure. The analogy should establish a knowledge structure.

14. An analogy is most helpful for low-ability, inexperienced students.

15. An analogy is more useful for conceptual understanding than for rote learning. A mnemonic or other memory-aiding device is preferred for teaching a fact.

Oculomotor Training For Pilots

Objective

The objective of this continuing effort is to evaluate a training program designed by the Athletic Perception Institute (API) to improve the oculomotor (eye movement) skills of Navy pilots.

Approach

Forty VF-124 student pilots were pretested on a device that measured their eye movement skills. They were then assigned to one of two groups matched for experience and pretest scores. One group, the experimental group, received API's oculomotor training program, which consists of 30 training sessions on recognition of visual stimuli projected tachistoscopically via two eye-movement devices, Tach Eye and Guided Eye. The other group, the control group, received no special eye-movement training. Both groups were given a posttest on their eye-movement ability. Student records on all subjects are being examined to reveal any differences in ability during critical parts of the VF-124 training pipeline that might be related to eye-movement skills. Recommendations for further work will then be developed based on the findings.

Results

The results of the training sessions on the experimental group are shown in Figures 3 and 4. Both the Tach Eye and Guided Eye scores improved as a result of training. No significant correlations were found between pretest or posttest scores and the number of flight hours reported by the trainees. Average pretest and posttest scores for the 15 experimental subjects who participated in both the pretest and the posttest were 56.58 and 68.37 respectively, compared to 56.16 and 57.09 for the 8 control subjects who participated in both tests.

An analysis of variance on the pretest and posttest scores showed: (1) no significant differences between the two groups of subjects in their pretest eye movement scores, (2) a significant increase in test scores between the pretest and the posttest in the experimental group, and (3) a significant difference between posttest scores of the experimental group and control group. As a check on the durability of the effect, a second posttest was administered to a small sample of subjects 2 months after training had been completed. Although the sample was too small to permit statistical verification, the second posttest results appeared to be identical to the first results, suggesting that no decrease in skills had occurred.

Conclusions

The oculomotor training had a significant effect on the eye-movement abilities of the subjects who received the training. Conclusions about the utility of this effect are dependent on data for each subject from the critical parts of the VF-124 training syllabus.

Remaining Tasks

All students will have completed training by the end of April 1983. Student records will be examined as they become available. Recommendations will then be formulated and COMNAVAIRPAC will be briefed concerning any further work warranted by the findings.

Note. This work was accomplished under FY82 work unit ZR000-01-042-06-01.06: Oculomotor Training for Pilots.

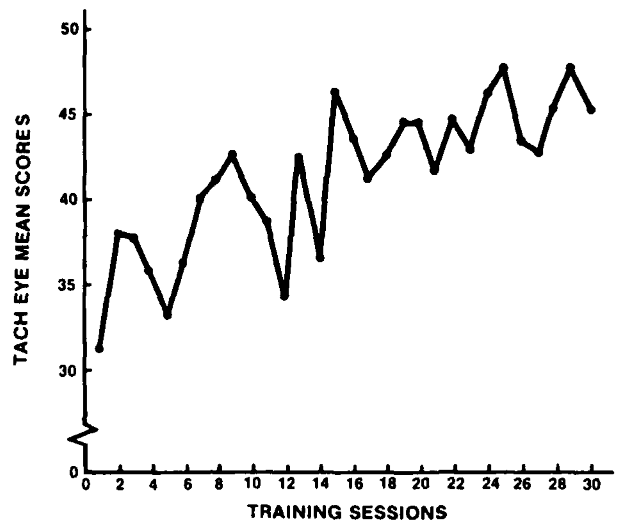

Figure 3. Tach eye performance improvement with training.

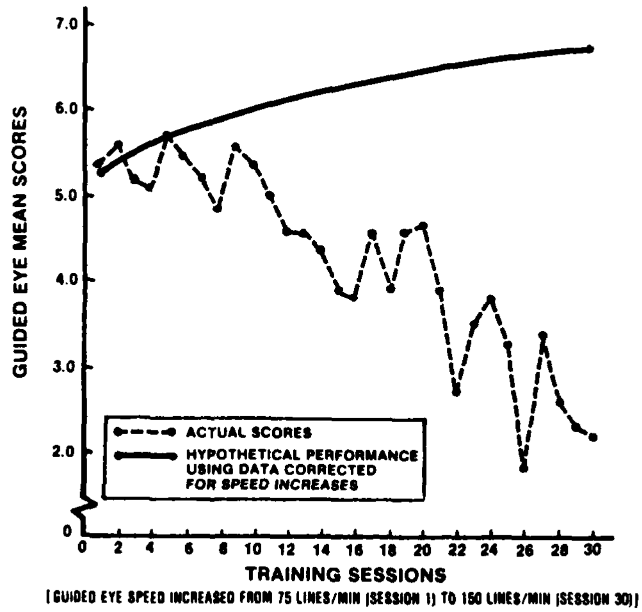

Figure 4. Guided eye performance improvement with training.

Acquisition Project Management

Problem and Purpose

The acquisition of the Navy's weapon platforms, systems, and equipments is a complex and involved business. The Naval Material Command and its systems commands are responsible for managing the Navy's acquisition process through project management; that is, each major system acquisition has a project organization with a project manager and a staff to manage it through the acquisition process.

The purpose of this effort was to investigate the different roles of the project manager and his staff with a view toward identifying possible intrarole conflicts (e.g., a task that is incompatible with the other tasks in the same role or with other roles that the incumbent has to perform). This project was initiated to develop knowledge to support future R&D related to acquisition project management.

Approach

The approach was to review literature, documents, and other written materials, and to interview project management personnel in the various support organizations within the SYSCOMs.

Two difficulties were encountered in this effort. First, there is a lack of uniformity in the definitions of key concepts, titles, and words used in the acquisition community (e.g., a "project manager" in one SYSCOM is a "program manager" in another). Second, there is a lack of reported research on any project personnel other than the project manager. Contract administrators, engineering managers, systems managers, and other second-echelon personnel apparently have not been the subject of research. This effort, therefore, was limited primarily to the role of the project manager and the SYSCOM organizations.

Findings

Some of the findings were not expected. Of 490 acquisition projects identified through documentation, less than half were being managed within the project management offices (PMOs). The majority of the projects are in the functional organizations of the SYSCOMs. Project offices tend to be associated with large unique acquisitions such as a class of ship or model of aircraft, whereas the functional organizations, being more technically oriented, manage the acquisition of systems that are common across weapon platforms (e.g., jet engines for aircraft or propulsion plants for ships).

Although military personnel make up less than 6 percent of the Navy's acquisition community, 58 of the 61 major PMOs have a military project manager. It is widely believed that routine reassignment of the military breaks the continuity of the project leadership; however, it was found that the deputy project managers, who usually are civilians, also exhibit a high turnover rate. Leadership discontinuity is not unique to the military in the acquisition community. Specified acquisition career ladders for civilians

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Note. This work was accomplished under FY82 work unit ZR000-01-042-08-03.02: Organizational Effectiveness of Program Management Offices. It has transitioned from IR to a reimbursable effort for the Chief of Naval Material: Acquisition Skills Inventory Evaluation.

do not exist, whereas the military have selection and rotation programs for developing acquisition leadership. Very few of the project top management people, both military and civilian, ever attend formal acquisition training, such as the 22-week acquisition management course at the Defense System Acquisition Management College. The two reasons given are that the course ties up executive talent too long, and it is only offered twice a year.

The literature describes project management as being different from that practiced in the traditional hierarchical organization. Project management usually requires more coordination of professional experts, such as engineers, contract administrators, and business managers, in areas of greater uncertainty than is typically found in the production-oriented hierarchical organizations. The project managers, therefore, must rely on their ability to persuade and negotiate and to use other professionals or organizations to accomplish project activities. The more technically competent the manager, the more successful he is at project management.

Presently, three criteria are cited for judging project outcome, viz., cost, schedule, and system performance. Many of the factors that influence these criteria are beyond reasonable control of the project managers and their staffs. Before any practical research on the roles and tasks comprising acquisition management can be considered, additional performance criteria will have to be developed.

INDEPENDENT EXPLORATORY DEVELOPMENT (IED) PROGRAMS

The Independent Exploratory Development (IED) program at NAVPERSRANDCEN was initiated in FY76. In FYs 81 and 82, programs were funded in the areas listed in Table 2. Selected projects within these areas are described in the remainder of this section.

IR/IED work units for FY83 are presented in Appendix A; and IR/IED publications and presentations, in Appendix B.

Table 2

IED Work Units for FY81-82

Independent Exploratory Development			Dollars (in thousands) FY81	FY82
ZF66-512-001:	IED SUPPORT TECHNOLOGY			
-010	Evaluation of Psychobiological Methods		15	5
-010-03.02	Color-specific Visual Event-related Brain Potentials as Related to Navy Display Systems	Dr. G. Lewis Code 17	15	5
-050	Factors Affecting the Acceptance of Change		45	50
-050-03.08	Impediments to the Implementation of Innovation[a]	Dr. J. Sheposh Ms. V. Hulton Code 16	45	50
-070	Methods for Improving Maintenance Procedures		15	0
-070-03.07	Remote Expertise for Maintenance	Mr. W. Nugent Code 17	15	0
-080	Production and Use of Graphics		50	80
-080-03.08	Theory of Graphic Representation	Dr. W. Montague Dr. J. Hollan Code 13	35	40
-080-03.09	Producing Effective Technical Graphics	Dr. T. Curran Code 13	15	40[b]
-090	Human Performance		0	10
-090-03.01	Human Performance in Detecting a Change in Target Location	Dr. R. Kelly Code 17	0	10
TOTAL			125	145

[a]Described in detail in previous IR/IED report, NPRDC SR 82-27.

[b]Being continued under FY83 work unit ZF66-512-001.004 (see Appendix A).

Visual Event-related Brain Potentials

Background

Traditional personnel assessment procedures have depended heavily on paper-and-pencil tests. Although these measures have predicted school and training performance quite adequately, their effectiveness in predicting job performance is less than desirable. This shortcoming is undoubtedly due, at least in part, to the difficulty in defining job performance and in devising reliable and valid measures of criterion variables. While continuing attention must be dedicated to imparting greater clarity and specificity to the meaning of job performance, it is believed that concurrent research emphasizing "process" rather than "content" information may be able to improve the prediction of job performance and, in addition, the design and use of system equipment and use. To this end, this Center's Biotechnology Laboratory was established with the primary objective of exploring the feasibility of developing and using a new technology in personnel assessment; namely, bioelectric and biomagnetic recordings from human brain, heart, and muscle. The major emphasis, to date, has been the development of methods and procedures to improve the prediction of on-job performance. Advances in the understanding of brain processes have provided procedures to assess individual differences and unique capabilities more accurately. Bioelectric measures, such as electroencephalograms (EEGs) and brain event-related potentials (ERPs), are very small signals recorded from the scalp. The EEG shows ongoing brain activity, while the ERP shows activity after vision and hearing have been stimulated (e.g., by light flashes or clicks to the ears). Brain processing may be assessed through ERP procedures and may provide more accurate and predictive information about human performance than methods currently being used by the Navy.

Results of this Center's research in laboratory and operational settings suggest relationships between ERP measures and various measures of academic and job performance. In the academic realm, our work suggests relationships between ERP measures and success in a Navy remedial reading program, Navy paper-and-pencil aptitude test scores, cognitive information processing, and reading ability. In research related to fleet performance, which includes recording ERP brain activity of pilots and radar intercept officers (RIOs), differences were found between the ERP measures of pilots and RIOs. For both groups, ERP records were related to job performance. Also, ERP records were shown to be potentially useful in predicting the performance of sonar operators and in assessing recruit promotion rate and attrition better than paper-and-pencil test scores. A main thrust of the research is to determine the feasibility of using brain activity measures to describe baseline performance and performance under psychological stress.

Brain Activity and Visual Processing

The increased sophistication and use of video display systems in Navy ship and aircraft control systems place greater demands on the personnel who operate them. Recent research has shown that ERP bioelectric procedures may be able to assess directly the performance of human visual and auditory systems. Color processing, color-form

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Note. This work was accomplished under FY81-82 work unit ZF66-512-001-010-03.02: Color-specific Visual Event-related Brain Potentials as Related to Navy Display Systems. It has transitioned from IED to reimbursable support from the Defense Nuclear Agency.

interaction, contour, element density, visual field stimulation, image quality, eye-movement efficiency, and information processing of visual images may be more readily and accurately assessed by biotechnology procedures than by verbal reporting from test subjects. The design of presentation formats for display information may be greatly improved when sensory and information processing capabilities are considered.

Recent major findings in ERP research relating to the effects of color and color interaction on brain function and perception have disclosed ERP components for three basic color processes; presumably, red, green, and blue. It appears that the red process develops most rapidly, followed by the green and then the blue. Various studies suggest that the components may be related to color processing at different levels of the visual system. Visual ERP data from the Center's Biotechnology Laboratory have shown marked differences among individuals. Greater individual differences were obtained with red, green, or blue stimuli than with white stimuli. The results suggest that subtle perceptual characteristics may be assessed through the ERP procedure.

It has been shown that pattern elements in visual stimuli produce specific response components in ERP records that vary with the nature of the elements (e.g., linear, curved), density of the elements (e.g., spatial frequency), and the region of the visual field being stimulated (e.g., upper versus lower fields). Sharpness of focus, or quality of image on the retina, may be assessed through the ERP. Individual differences in the ERP to optimal spatial frequencies and binocular summation may be important for assessing personnel performance and man-machine interface relationships.

The effects of color and color interaction on brain function and perception have been demonstrated in the Center's Biotechnology Laboratory. Figure 5 presents sample data from two subjects showing the sensitivity of ERP data to individual differences. The visual stimulus was a green-black checkerboard pattern. The eight channels of visual ERP data for subject "A" are overlaid on those for subject "B." Calibration, polarity, and time base information are displayed along with the pre-stimulus waveforms. Post-stimulus waveform amplitude (standard deviation, SDμV) and mean (MNμV) values were computed and displayed for each subject's electrode site. The waveforms in the left column were derived from the left hemisphere (LH). The waveforms from top to bottom were from the front to the back of the head at frontal (secondary association area--F3), temporal (auditory reception area--T3), parietal (primary association area--P3), and occipital (visual reception area--O1) sites. Right hemisphere (RH) ERP data are represented in the right column similar to LH data (F4, T4, P4, O2). The top two values for each site represent the standard deviation and mean for subject "A," and the bottom two values, those for subject "B." Few similarities are apparent in the ERP records of the two subjects.

Figure 6 shows a single subject's ERP waveforms produced by red checkerboard stimuli in the same display format as in Figure 5. The data were obtained about 2 hours apart. A great amount of intrasubject reliability may be seen, particularly at sites located at the back of the head (parietal/occipital). Color stimulation produces high intrasubject reliable waveform records, in contrast to high intersubject variability.

Analyses of these records may include a "template" or pattern recognition as well as cross-correlation and auto-correlation procedures. A dramatic way to assess the similarities and differences in ERP waveforms has been recently developed in our laboratory. Data are displayed and analyzed over the color video monitor. Either black and white hardcopy or color 35mm slides may be made of the displayed data. The color videographic system can display up to 256 colors simultaneously. We take advantage of this capability by overlaying two separate displays of data at one time in different colors.

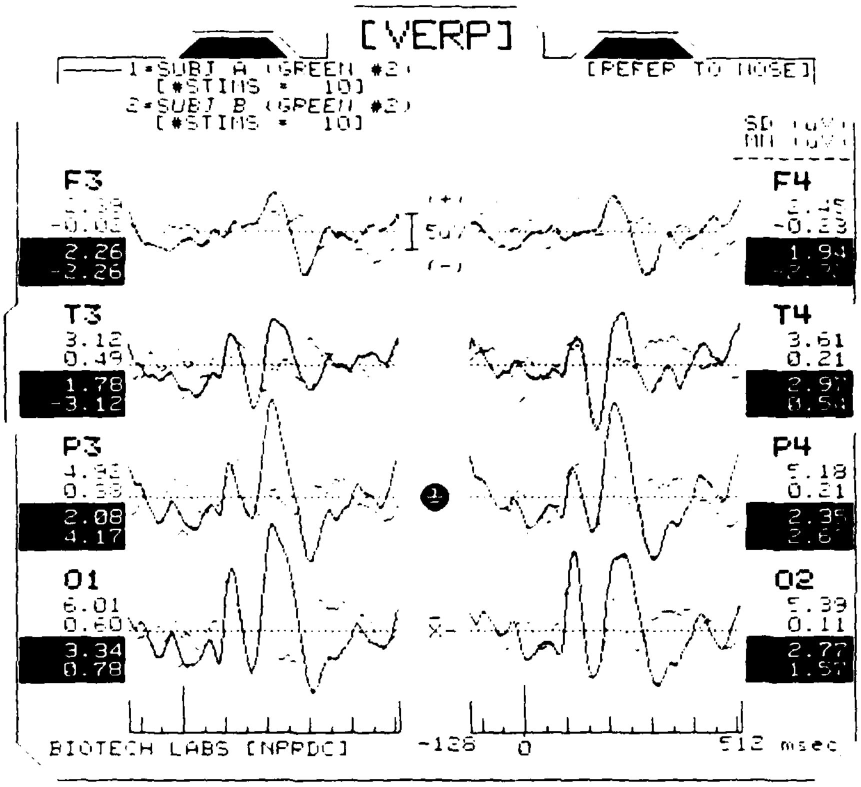

Figure 5. Visual (green stimuli) ERP waveforms for two subjects.

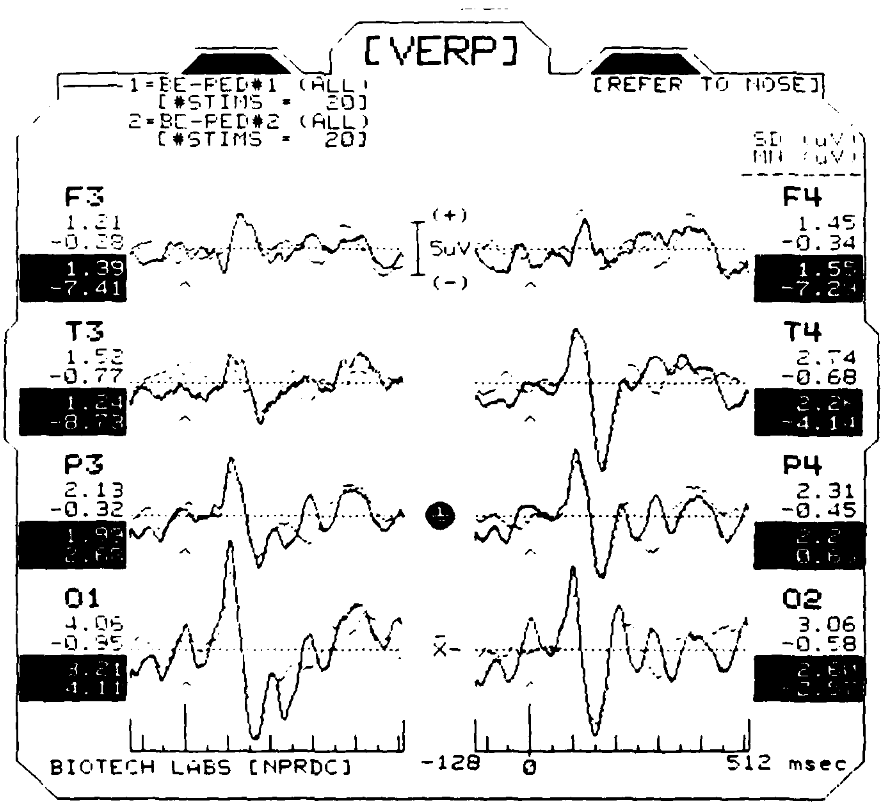

Figure 6. Visual (red stimuli) ERP waveforms recorded about 2 hours apart for a single subject.

Where the waveforms do not overlap, the original color is seen (e.g., yellow and green or red and blue). Where the waveforms do overlap, however, the new combined color may be seen, such as purple. Such color-coding makes it very easy to see those ERP waveform areas that are stimulus-dependent (similarities) and those that are unique between subjects (differences). Similarities and/or differences within a subject may also be observed when different stimuli are presented (e.g., visual, auditory). Detailed analyses of ERP waveform features are underway.

As may be deduced from the above account, most of the Center's effort to date has been to develop a laboratory capability for recording and analyzing electrical signals indicative of brain and muscle activity and to continue building a data base for these phenomena under a variety of baseline and duress conditions. It is believed that results already obtained linking these data to measures of ability warrant continuation of this effort.

Remote Expertise for Maintenance

Background

Shore-based technical assistance is generally requested when a ship has determined that its own unit personnel are unable to diagnose and repair an equipment casualty. Although such casualties may constitute only a limited portion of the maintenance problems encountered in the fleet, they are especially detrimental to overall operational readiness because of the lengthy delays usually encountered before outside technical assistance is provided. One possible way to reduce the amount of time that a ship spends in a degraded state of equipment readiness at sea is to provide a reliable and effective two-way communication link between expert technicians on shore and deployed units of the fleet using modern communication satellite technology.

The technological feasibility of establishing a remote communications assistance network was demonstrated in a project sponsored by the Naval Sea Systems Command (NAVSEA 62C), entitled Shipboard Engineering Assistance for System Test and Repair via Satellite (SEASTARS). The SEASTARS project team was successful in demonstrating the technological compatibility of various communications accessory equipments that would support such a network, as well as the methodology to be used in integrating these units with a commercially available communications satellite system. However, the project team did not demonstrate (either directly or through simulation) the problem-solving capabilities of this performance-aiding concept. This study was undertaken to provide such a demonstration and to identify factors that might affect the use of such a procedure when troubleshooting Navy equipment casualties.

Approach

Equipment casualties representative of those requiring outside technical assistance were inserted in the AN/SQR-17 sonar detecting-ranging set in two demonstration sessions. For each session, an SQR-17 maintenance instructor from the Fleet Anti-Submarine Warfare Training Center, Pacific, San Diego served as the remote maintenance technician (or expert), while 2nd and 3rd class surface sonar technicians (STGs) from the fleet served as shipboard (or attendant) technicians. A two-way voice communication link was established between the expert and attendant technicians via an audio intercom. For session 1, a video link was also provided that allowed the expert to view those portions of the equipment that would provide information of potential relevance to the troubleshooting situation. For session 2, the expert was instructed to use the video link only in those cases where he could no longer proceed with troubleshooting based on audio information alone.

The attendant technicians were stationed at the equipment site and were responsible for reporting the symptoms associated with each casualty to the expert technician. They were also responsible for performing various fault isolation tests using standard Navy test equipment and for removing and replacing printed circuit cards as directed by the expert.

The expert technician, who was stationed in an adjacent room, was instructed to advise the attendants verbally in troubleshooting and repairing equipment casualties and,

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Note. This work was accomplished under FY81 work unit ZF66-512-001-070-03.07: Remote Expertise for Maintenance. A more extensive discussion is presented in NPRDC SR 82-15 (Nugent, 1982) (AD-A111 525). Further evaluation of this concept has been transitioned from IED to project element 62763N, work unit 522-801-014-03.02.

as applicable, to direct the television camera to those portions of the sonar system or supporting test equipment.

Three troubleshooting problems were inserted in the SQR-17 for each session. The faults were identical in both cases but their order of presentation varied between sessions. For each problem, conversations between the expert and attendant technicians, as well as the total time spent in troubleshooting, were recorded.

Findings

The remote maintenance technicains were successful in solving five of the six problems inserted in the SQR-17 sonar. The problem that was not solved was terminated due to time limitations imposed by the testing schedule. Conversation time between the expert and attendant technicians accounted for an average of only 17 percent of the total time spent in troubleshooting each problem. When visual information was provided, the expert technicians were interested in viewing only limited portions of the sonar set and supporting test equipment. During session 2, an imprecise verbal description of the equipment casualty symptoms associated with one troubleshooting problem resulted in the expert technician pursuing a lengthy and ineffective troubleshooting strategy. When the expert requested video information to confirm the casualty symptoms, he was able to locate and solve the problem in less than 30 minutes.

Conclusions

To the extent that the current study was able to simulate the conditions under which remote communications assistance would be provided, the feasibility of this concept was successfully demonstrated. The large proportion of time spent in nonconversational activity for each troubleshooting problem indicates that the communications link could be used intermittently during the course of a remote communications assistance event. Expert maintenance technicians must be provided with a precise verbal description of all relevant symptoms of an equipment casualty to facilitate timely and effective troubleshooting strategies when only audio link remote communications assistance is employed.

Graphic Representation for Learning

Introduction

It is generally believed that graphic presentations aid learning and comprehension and create interest. Dynamic computer-controlled graphical displays now make it possible to simulate not only events but also aspects of those events that have important instructional significance. However, the conditions under which the use of graphics will enhance instruction have yet to be described theoretically and substantiated empirically.

Like any notational system, graphics are better at representing and communicating certain types of information than are other types. Thus, the effectiveness of graphics depends upon the kind of information to be conveyed, as well as the capability of the person to whom that information is presented to understand the representation.

One primary reason for not designing graphics into instruction is the lack of an integrated cognitive theory of graphical presentation. In addition, the use of graphics can add substantially to the cost of instruction, especially if the presentation is dynamic and interactive. However, the cost of including dynamic graphical presentations with which the student can interact is declining rapidly as the cost of computer capability declines.

Problem

Recent research reviews indicate that the inclusion of graphical instructional material does not in itself guarantee an increase in instructional effectiveness. Reviewers point out that the increase in instructional effectiveness is largely assumed. The topics usually addressed are how to select the "best" graphical medium and how to design displays for presenting graphic material. The reviewers also conclude that there are conditions under which graphics may be an important adjunct to the instructional process, but currently there is no way to identify these conditions.

Graphics and other media cannot be studied profitably by themselves as has been presupposed in the research literature. Any approach must conceptualize, classify, and analyze what is to be learned or communicated, determine which media are appropriate, and relate these factors to the cognitive processes of the learners.

The essential differences between different media or forms of presentation are not the physical differences in the ways signals are presented, such as television or films or static pictures. Rather, the differences are in the ways in which particular presentations structure, convey contents, and influence the cognitive structures in a learner's mind. Various media may convey the same symbols and, therefore, the same content. There has been little research on how symbols affect mental representations and how they function to develop mental skills. Furthermore, there has been little investigation of the interaction between a student's already developed cognitive skills and knowledge and the effectiveness of various forms of symbolic presentation on new learning and performance.

An important idea drawn from work in artificial intelligence is that a key step is to represent a problem in a way that makes the solution transparent. The attempt is to map the task onto the strategies available for problem solution. A format must be found that

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Note. This work was accomplished under FY81-82 work unit ZF66-512-001-080-03.08: Theory of Graphic Representation. Evaluation of the programs developed to provide instruction in maneuvering board problem solving has transitioned from IED to program element 62763N, work unit RF63-522-801-013-03.03: Computer-based Techniques for Training Procedural Skills.

permits a person to perform certain tasks that would be difficult or impossible if presented in another format. For example, mathematical and geometrical diagrams are meant to aid problem solving, as are scientific diagrams, tables, nomograms, and the like. Events or processes, normally invisible or unseeable, help learners understand them (and perhaps represent them cognitively) and the consequences of various actions. What is needed is a design technology to guide the specification of graphic formats that will aid people's understanding and problem solutions.

Objectives

The objectives of this project were to review the literature and summarize the state of our understanding regarding learner representation of knowledge, to suggest how graphical presentation can be used to communicate the representations needed to perform tasks, and to conduct empirical demonstrations of the effectiveness of new forms of representing material for learning.

Approach and Results

We undertook to develop and test the effectiveness of a different analogical representation of simple electronic circuits encountered by Navy recruits in the Basic Electricity and Electronics (BE/E) course. In addition, we developed an interactive program showing relative motion on a radar-like display along with the same information displayed on a geographic plot. This was intended to facilitate student understanding of a relative motion required of personnel such as tactical action officers and operation specialists.

Graphical Representations of Relative Motion. A microcomputer-based interactive graphics program was constructed to provide conceptual instruction in maneuvering board problem solving. The maneuvering board is a job aid to help determine how to maneuver ships in close proximity to one another. In current formal training on maneuvering board use and the solution of relative motion problems, most failure rates are about 20-30 percent for both officers and enlisted personnel. The difficulty appears to be understanding the basic principles of relative motion. Prior research suggested that students trained with a conceptual model that demonstrated the relation between relative and geographic motion had better recall for the procedures.

The initial development was a computer-based system that provided students with a conceptual model of the relationships between events in the real geographic world and elements of the maneuvering board plot. A simulation program provided a bit-map graphic display of relationships between relative motion and geographic plots of ship movements on a TERAK microcomputer. The graphics display design was based on an analysis of the conceptual difficulties experienced by failing students.

The system was used on a pilot basis at the Fleet Combat Training Center, Pacific. Instructors found it useful as a tutorial aide when working with students having difficulty in learning the material. In its original form, the simulation was difficult for students to use (Hutchins & McCandless, 1982). This resulted from requirements for typing and moving the cursor around on the screen. The programs were later transferred to a more powerful microcomputer system with better graphics and a better interface with students. In addition, the TERAK version was further refined to be easier for students to use.

Graphical Representations of Basic Electronics Concepts. It is common in instruction to use analogies to teach students new material. A main problem is that a particular analogy can help or can hinder learning, depending on several factors. For example, the congruence between objects and object attributes in the material to be taught and those in the analogy determine much of the analogy's effectiveness. in addition, the familiarity or understandability of the relations or processes in the analogy to the learner is important. If students don't understand the analogy itself, it is of doubtful value for learning new material. Also, the analogies used to represent novel materials to a new learner may need to be quite different than those used for a more experienced or knowledgeable person.

Under contract with NAVPERSRANDCEN, researchers at the Learning Research and Development Center (LRDC) of the University of Pittsburgh studied some aspects of this problem using materials taken from the Navy's BE/E course. Students traditionally have had problems in learning some of the basic concepts taught in this course. For example, a significant proportion of the attrition from the course seems to be due to failure to understand how combination series-parallel circuits work. Changes made to course materials that have not recognized this problem have had little effect. The LRDC work found that students don't understand the analogies used to teach about circuit relations, make wrong inferences about events occurring because of changes in the circuit, and make consistent errors. This led to the idea that a different representation or analogy might be more appropriate for these learners.

The BE/E course uses a version of the "moving crowd" analogy to teach the relations among current, voltage, and resistance in simple series circuits. Students are told to think of current as the rate at which a crowd of objects (electrons, balls) moves along a path. The voltage applied from the battery corresponds to the push or force to get the objects in motion. Resistance is to be thought of as friction and depicted by a rough or crooked path. The moving-crowd analogy leads to some straightforward predictions about the relations between voltage, resistance, and current: (1) as voltage increases or decreases, current increases or decreases, (2) as resistance increases or decreases, current decreases or increases. The analogy makes no clear predictions about circuit relations at the level of individual resistors, however, and even leads to some incorrect predictions. For example, when current flows through a resistor, there is a drop in voltage across that resistor directly proportional to the rate of current flow and the amount of resistance. The sum of these voltage drops across all resistors in series equals the voltage applied. Furthermore, current is the same at all points in a series circuit. This is not clear in the moving-crowd analogy. In fact, the opposite might be predicted if friction (resistance) is thought to impede or slow current flow. Thus, current would be expected to slow down as it passes each resistor. Similarly, since voltage is "dropped" at each resistor, and voltage is what "pushes" the crowd (current), one might expect current to slow as it moves through the circuit. Both of these inferences, one based on friction and the other on voltage loss, violate the constraint that current is the same everywhere in a series circuit. Errors like these are common among students learning BE/E.

A new graphical representation of series circuits developed at LRDC is easily understood by students because of its familiarity and concreteness. It graphically depicts the simultaneous constraints at both the entire circuit level and at the local resistors. Voltage is represented as a stack of (poker) chips; and resistors, as boxes containing slots equal to the resistance. In a series circuit, the chips are distributed equally among the resistor slots. As illustrated in Figure 7, R1 is 2 ohms (a box with two slots) and R2 is 3 ohms, for a total of 5 ohms in the circuit. When 10 volts (chips) are applied, they are distributed equally among the slots. The 2 chips per slot represents 2 amperes of current

in the circuit. Voltage drop for a resistor is shown by the total number of chips in each resistor's slots (i.e., 4 volts for R1 and 6 volts for R2). This model maps geographically into the constraints specified in Ohm's Law equations.

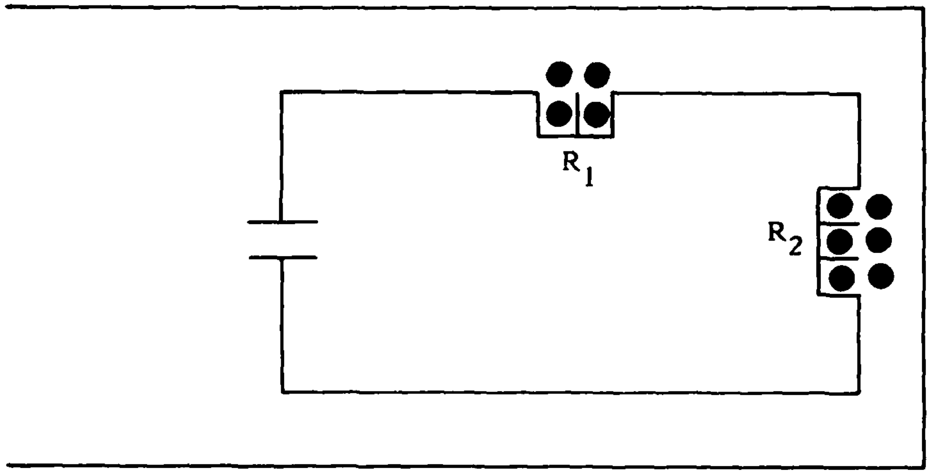

Figure 7. Graphical representation of series circuits.

NAVPERSRANDCEN researchers adopted this approach, redesigned materials selected from the first part of the BE/E course, and arranged them into two sets of workbooks. One set maintained the standard analogies and circuit representation. In the other, the chips representation was added as a learning aid. Groups of students studied the materials and took the regular progress tests for 2 days prior to the time they began the BE/E course.

In terms of overall performance in the course, there were no differences between the groups. However, on the few problems included in the progress tests that were diagnostic of the misinferences discussed above, 85 percent of the chips group got such problems correct, compared to 50 percent of the standard group. Three important points stem from this work. First, systematic analysis of the relations between analogous representations and the systems that students are to learn can reveal misunderstandings that lead students to make errors; these misunderstandings make learning difficult. Second, once these misunderstandings are identified, they can be corrected, perhaps by designing a simpler, more concrete analogy. Third, interactive, diagnostic testing procedures can assist in probing student misunderstandings and in correcting them. Diagnostic testing is necessary because errors of misunderstanding are revealed only by a few test problems. In the current course, such test questions are asked infrequently (10-15% of the items). It was only on the "diagnostic" questions that they differed. Automated systems that can present those circuit problems and assess a student's reasoning about each part or component will considerably enhance our ability to detect learning problems and make learning more efficient.

To this end, we developed an interactive simulation of the model on a microcomputer in the form of a program (TESTER) that allows an instructor to develop tests. Various aspects of problem-solving performance can be recorded. Both standard and chips representation forms of the test are available. Evaluation of this program is continuing.

Human Performance in Detecting a Change in Target Location

Background

An idealized command and control problem was developed to investigate human decision-making performance. Specifically, the task for the observer was to decide whether or not a target has changed location from an earlier fix. Briefly, the observer views a sensor display that shows a noisy sample of N reported locations of the target. The noise is produced by a statistical distribution (the circular normal density) and each datum on the display appears as a dot that encodes the reported (x,y) coordinates. If the target has not moved, the dots will tend to cluster around the origin, which represents its last known position. If the target moved since the last fix, the dots will tend to cluster around some point offset from the origin. Based on the noisy sample, the observer must decide whether or not the target has moved (at least R units) from its last known location. It is assumed that the target is stationary at the time the data are observed and that all directions of movement are equally likely.

This decision-making task represents a typical surveillance problem. For example, the "target" might be a military force under surveillance or an underwater object that is subject to drift. We seek to derive an optimal information-processor for assessing this decision-making skill.

Decision Theoretic Analysis

As shown in Figure 8, there are two states of nature, S_O and S_R. In state S_O, the target is at the origin, its original location. In state S_R, the target has moved R units to the location ($\mu_x \mu_y$) with direction of movement given by the angle θ, which is a uniform random variable on the interval $[0, 2\pi]$. The problem is to decide whether the target has moved or not; that is, whether S_O or S_R is true.

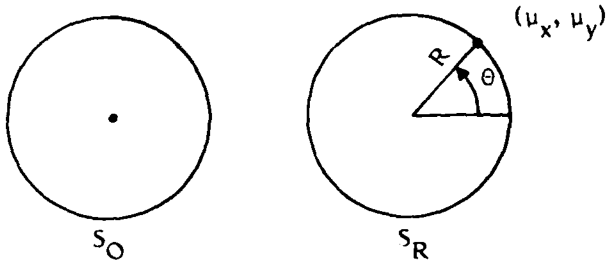

Figure 8. Two states of nature.

The task for the decision maker is illustrated in Figure 9. He has been told that an earlier fix placed the target at the center of the circle. At the left is a sample of later data from S_O; and at the right, a sample of later data from S_R. The decision maker sees <u>one</u> such display or the other and must decide whether S_O or S_R is true; that is, whether the target has moved. Clearly, in this example, the display on the right indicates that the target has moved, whereas the display on the left indicates that it has not moved. With fewer observations, this task becomes more difficult.

<u>Note</u>. This work was accomplished under FY82 work unit ZF66-512-001-090-03.01: Human Performance in Detecting a Change in Target Location.

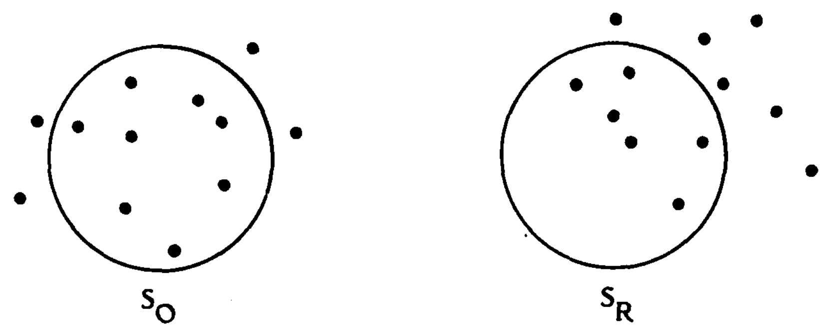

Figure 9. Two typical displays with N = 12.

The decision maker is required to minimize the expected cost of decisions, where the <u>a priori</u> probabilities of S_O and S_R are p_O and p_R. Costs are incurred as shown in the following cost matrix:

		S_O	S_R
Decision:	"O"	O	C_O
	"R"	C_R	O

<u>Optimal Decision Rule</u>

Standard Bayesian analysis leads to the following minimum-cost decision rule:

> Decide "R" (that the target has moved) if, and only if, the distance $\underline{d}$ to the centroid of the data exceeds a critical value d*.

The centroid is the point $(\bar{x},\bar{y})$ given by the means of the x and y coordinates. The critical distance d* involves a Bessel function and depends upon the sample size N, the error variance σ^2, the radius R of the circle, the costs C_O and C_R, and the priors p_O and p_R. The quantity d* is a decreasing function of N/σ^2 and, for symmetric costs and priors, approaches R/2 in the limit, as illustrated in Figure 10.

In the context of the theory of signal detectability (Green & Swets, 1966), we may regard the movement of the target as a "signal" to be detected and obtain the probability of detection and the probability of a false alarm. These are, respectively, the probabilities that the distance $\underline{d}$ to the centroid of the data exceeds $\underline{d}$*, given either S_R or S_O.

Given S_O, the quantity Nd^2/σ^2 turns out to be a chi-square random variable with 2df. Given S_R, the same quantity is a noncentral chi-square random variable with 2df and noncentrality parameter R^2.

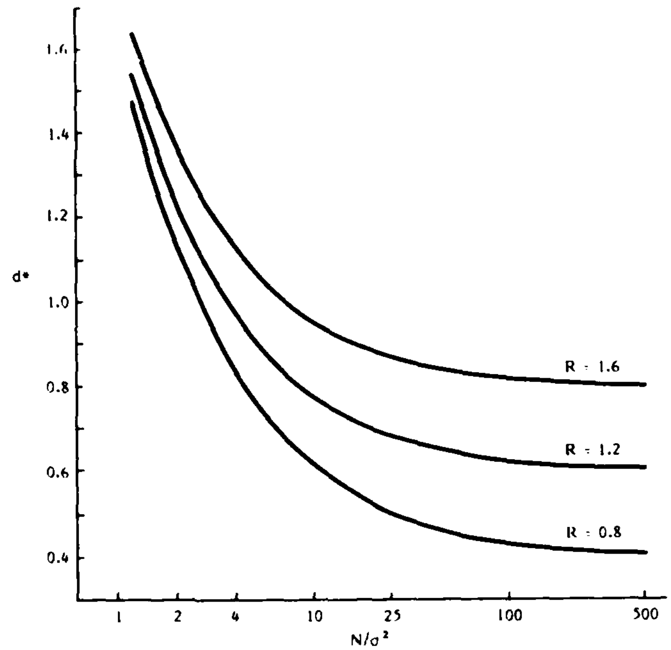

Figure 10. Critical distance $\underline{d}$* as a function of R and N/σ^2.

Figure 11 exhibits the receiver operating characteristic, which plots in the unit square the detection probability versus the false alarm probability. The curves shown are for sample sizes N = 1, 3, 5, 7, 9 with R = 1.2 units and $\sigma^2 = 1$. For a given sample size, a decision maker who uses the distance statistic $\underline{d}$ is constrained to the given curve. The points marked "o" designate optimal performance for the case with symmetric costs and prior probabilities.

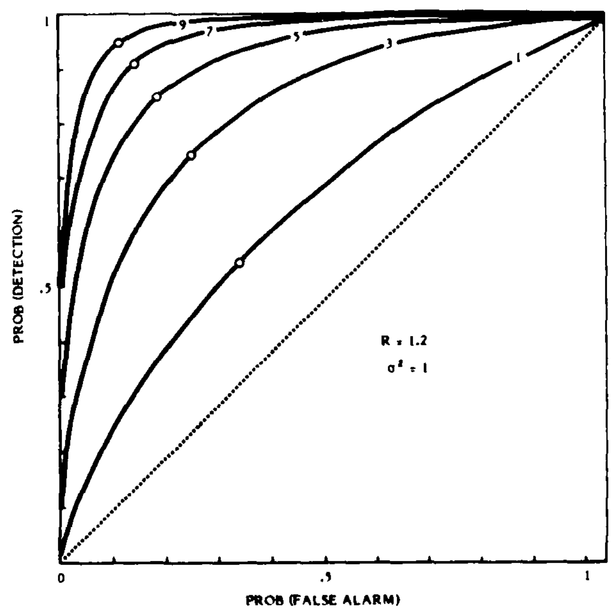

Figure 11. ROC curves for R = 1.2, $\sigma^2 = 1$, and sample sizes N = 1, 3, 5, 7, and 9.

AS-IF Detector

The optimal decision maker quite properly considers all directions θ of the target's possible movement. A quite different detector is now considered that forms the maximum likelihood estimate $\hat{\theta} = \arctan(\bar{Y}/\bar{X})$ and then tests the origin against the simple alternative that the target has moved R units at the angle $\hat{\theta}$. This decision maker behaves "as if" $\hat{\theta}$ were the only possible θ and is called an AS-IF detector.

Analyzing this detector for $(C_R p_O)/(C_O p_R) = 1$ yields the decision rule: Decide "R" if and only if $d > R/2$. Note that this rule does not depend on N or σ^2.

Referring again to Figure 11, the digits 1, 3, 5, 7, 9 are, in fact, the operating points for the AS-IF detector. This detector is always on the same curve as the optimal decision maker because they both use the same test statistic d. However, the AS-IF detector is more disposed to assert that the target has moved. He will always have higher detection and false alarm probabilities than is optimal to minimize expected cost.

Relation to Signal Processing

After some searching, it was discovered that the solution to the spatial task of detecting a change in target location is not an original one. The solution may be "new" but it is identical to that for a well-known problem in acoustic and radar signal processing--that of detecting in Gaussian noise a sinusoid signal known exactly except for phase. There is a strict isomorphism between these two problems; they are indeed the same problem and have the same solution. The unknown phase of the sinusoid is the unknown θ in our problem. The amplitude of the envelope output by the narrow-band filter is precisely the distance statistic that arises in our target movement detection task. The Rayleigh-Rice probability density functions that arise in the signal-processing domain have as their counterparts the chi-square and noncentral chi-square probability density functions.

Human Performance

Some human performance data were obtained for this task with equal prior probabilities (so that there is a 50-50 chance that the target has moved). The observer earns 10 points for each correct decision and loses 10 points for each incorrect one. Three observers were tested for approximately 600 plays at each of the sample sizes N = 1, 3, 5, 7, and 9. A microcomputer drove a graphics terminal that always displayed the circle of radius R and plotted the N samples as points in the plane. Feedback--right or wrong--and the correct location of the target were given after each play.

Two characteristics of human performance are of interest. First, the observers were not strictly optimal. Their performance only approximated the ideal, and, although they did better as the sample size increased, they failed to extract all the information available in the larger sample-size conditions. Second, the observers were not behaving like the AS-IF detector. They were using something like the distance statistic d and adjusting their criterion as the sample size increased. Figure 12 shows this clearly. Here

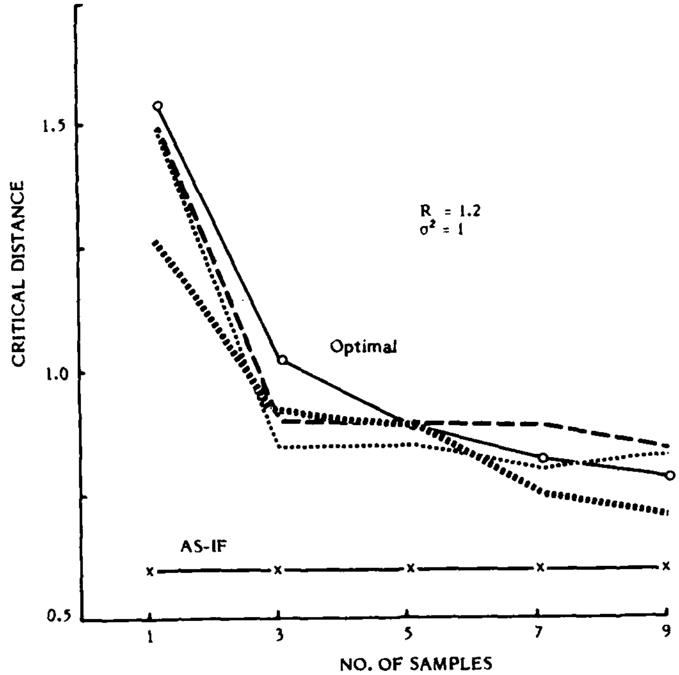

Figure 12. Estimated d* criteria for three observers (dashed curves) as function of sample size. Optimal and "AS-IF" performance are plotted for comparison.

the critical distance is shown as a function of N. The open circles show how d* properly decreases for the optimal detector. The d* criteria were estimated for each of the three observers by taking that distance d for which they were equally likely to respond "R" or "O." These are plotted as the three dashed curves in Figure 12. Note that they are "close" to the ideal d*, and it is clear that the AS-IF detector must be rejected as a possible model for the observers.

Sequential Decision Problem

Up to now, the sample size N has been treated as fixed. Next, consideration will be given to the more interesting sequential decision problem in which the decision maker, after each observation (sample), must decide either "O" (the target is at its original locus), "R" (the target has moved), or elect to buy another sample at some cost. Correct terminal decisions are worth, say, 10 points. Incorrect terminal decisions cost 10 points. Let the price of a sample be 1 point. Again, equal priors are used and the decision maker is to play the sequential game so as to maximize his expected payoff.

Now, the optimal decision maker will adopt a decision rule of the form shown in Figure 13. For an observed distance d to the centroid that exceeds the upper curve, the decision maker decides that the target has changed location. If d is beneath the lower curve, the decision maker decides the target has not moved. For values of d between the bounds, the observer should defer and buy another sample. The bounds are, of course, dynamic and vary as a function of the number of samples already in hand.

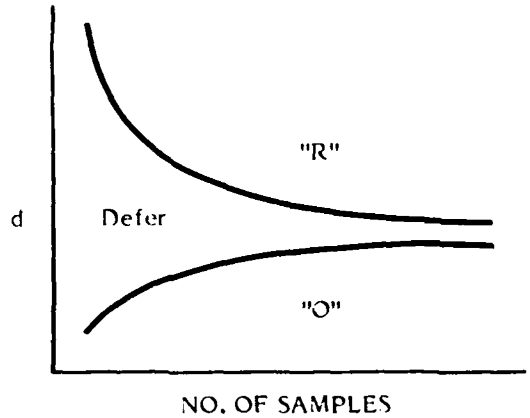

Figure 13. Optimal decision bounds as a function of sample size in the sequential problem.

The Wald (1947) approximations were used for the decision boundaries that are usually given in terms of the desired error probabilities, α and β. The "quasi-optimal" bounds were found by running Monte Carlo simulations based on the Wald boundaries, and then searching the Wald space for the maximum expected payoff. Figure 14 shows these optimal bounds (the solid lines) for the first six samples of the sequential game in which $R = 1.2$ and $\sigma^2 = 1$. Notice incidentally that, for this game, the optimal decision maker never decides that the target has not moved with less than three samples in hand. However, a single sample with a large distance from the origin (about 2.75 units) can trigger the decision that the target has changed location.

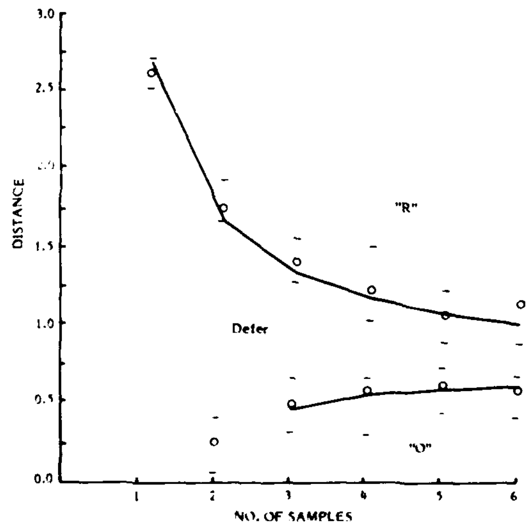

Figure 14. Optimal decision bounds (solid curves) and estimated bounds for human observer (o's) for the sequential game with $R = 1.2$, $\sigma^2 = 1$.

The circles plotted in Figure 14 are the data of a well-practiced observer for 500 plays of this sequential game. The upper circles are the observer's indifference points between the terminal decision "R" and the decision to "buy another sample." The lower circles are the indifference points between the decision "O" and "buy another sample." The dashes above and below each point indicate the extent of variability in the observer's bounds. For this observer, there is surprisingly good conformity with the optimal bounds. Data from other observers also clearly follow the form of the optimal prescription.

Conclusions

The quantification and understanding of human performance are essential to the design of effective surveillance systems for command control operations. Therefore, human abilities and limitations need to be considered in order to guide the design of improved surveillance displays and software algorithms. In real systems, these abilities and limitations are all too often ignored--and result in expensive hardware fixes, software modifications, or just plain degraded systems performance. The preliminary data given here, however, speak quite well for the human as a spatial processor and decision maker in a task that is by no means straightforward.

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APPENDIX A

IR AND IED WORK UNITS FOR FY83

IR and IED Work Units for FY83

61152N	In-House Independent Laboratory Research		FY82	FY83
ZR000-01-042	In-house Laboratories			
.003	Cognitive Speed and Learning Potential	Dr. B. Rimland AV: 933-6122 Code 14	21[a]	25
.005	Models and Measures of Human Performance	Dr. R. C. Sorenson AV: 933-2231 Code 14	9[b]	80
.010	Evaluation of Oculomotor Training for Pilots	Mr. W. Thode AV: 933-7122 Code 13B	14[c]	15
.013	Multiple Criterion Optimization Techniques	Dr. T. Liang AV: 933-2971 Code 11	0	30
.014	Enhancing Understanding of Electronic Circuits	Dr. W. Montague AV: 933-7121 Code 13A	0	30
.015	Human Performance in Detecting Change in Target Location	Dr. R. Kelly AV: 933-2081 Code 17	0	60
.016	Comparison of Classification Procedures	Dr. G. Wilcove AV: 933-6803 Code 15	0	30
.017	Generalizable Cognitive Strategies	Dr. M. Baker AV: 933-6803 Code 15	0	30
				300

[a]Conducted under FY82 work unit ZR000-01-042-04-01.08.

[b]Conducted under FY82 work unit ZR000-01-042-04-01.10.

[c]Conducted under FY82 work unit ZR000-01-042-06-01.06.

IR and IED Work Units for FY83 (Continued)

62766N	Laboratory Independent Exploratory Development		FY82	FY83
ZF66-512-001	Special Laboratory Support/IED Support Technology			
.004	Technical Graphics	Dr. T. Curran AV: 933-6466 Code 13A	40[a]	40
.006	Military Officer Career Development: A Multiple Cohort Longitudinal Analysis	Dr. R. Morrison AV: 933-6803 Code 15	0	15
.007	Cognitive Factors in Learning and Retention	Dr. J. Ellis AV: 933-7121 Code 13A	0	30
.008	Self-defense Tactical Trainer	CDR D. W. Anderson AV: 933-7121 Code 13A	0	20
.009	Market Segmentation Methods	Dr. S. Hearold AV: 933-2371 Code 15	0	40
.010	Video Game Techniques	Mr. W. Thode AV: 933-7122 Code 13B	0	10
				155

[a]Conducted under FY82 work unit ZF66-512-001-080-03.09.

APPENDIX B

IR/IED PUBLICATIONS AND PRESENTATIONS

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